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ANNUAL REPORT

STRONTIUM

By Joyce A. Ober

1990

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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STRONTIUM

U.S.
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Director

September 1991

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COVER PHOTO:
One of the most recognizable uses for strontium is in pyrotechnics. Brilliant red fireworks and signal flares get their color from the combustion of strontium nitrate. Strontium is used by the military in tracer bullets as shown in this photo.

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STRONTIUM

By Joyce A. Ober

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The largest consumption of strontium compounds domestically and internationally was in the production of color television picture tube faceplate glass. Strontium carbonate, produced by processing the mineral celestite, was the most important strontium compound produced. Chemical Products Corp. (CPC) of Cartersville, GA, was the only U.S. producer of strontium compounds from celestite. CPC produced compounds from imported material because there were no active celestite mines in the United States.

Strontium occurs commonly in nature, averaging 0.034% of all igneous rock; however, only two minerals, celestite and strontianite, contain strontium in sufficient quantities to make its recovery practical. Of the two, only celestite has been found to occur in deposits of sufficient size to make development of mining facilities currently attractive. Celestite, the most common strontium mineral, consists primarily of strontium sulfate. Strontianite, the second most common mineral, consists primarily of strontium carbonate. Strontianite would be the more useful of the two common minerals because strontium is used most commonly in the carbonate form, but few deposits have been discovered that are suitable for development.

TABLE 1

SALIENT STRONTIUM STATISTICS

(Metric tons of contained strontium unless otherwise noted[1])

	1986	1987	1988	1989	1990
United States:					
Production, strontium minerals	—	—	—	—	—
Imports for consumption:					
Strontium minerals	13,200	16,900	18,100	12,000	21,500
Strontium compounds	4,300	5,000	7,800	11,300	11,800
Exports[2] (compounds)	680	1,600	3,000	3,200	1,300
Shipments from Government stockpile excesses	—	—	—	—	—
Price, average value of mineral imports at port of exportation, dollars per ton	r$170	r$95	r$85	r$76	$86
World production[3] (celestite)	r153,000	r202,000	r236,000	r234,000	e235,000

eEstimated. rRevised.

[1]The strontium content of celestite is 43.88%, which was used to convert units to celestite.

[2]Export data are obtained from the Journal of Commerce Port Import/Export Reporting Service.

[3]Excludes China and the U.S.S.R.

DOMESTIC DATA COVERAGE

The sole U.S. strontium carbonate producer voluntarily provided domestic production data to the U.S. Bureau of Mines. Production and stock data, however, were withheld from publication to avoid disclosing company proprietary data.

The Bureau also estimated the distribution of strontium compounds by end use. Of the 10 operations to which a survey request was sent, 8 responded. The information collected from this survey represents about 100% of the end use data shown in table 2. Consumption for the nonrespondents was estimated using reported prior-year consumption levels.

ANNUAL REVIEW

Issues

The Government of Mexico requested a waiver of the competitive need limit for strontium carbonate. Under the General System of Preferences, Mexican strontium carbonate entered the U.S. duty free. A tariff was assessed against imports of strontium carbonate from Mexico when those imports represented more than 50% of total strontium carbonate imports. The duty free status was revoked in July 1990. The waiver was expected to be approved because there was no opposition from the domestic strontium carbonate producer, and the consumers favored the proposal.

Production

Although there have been no active celestite mines in the United States since 1959, celestite deposits have been identified nationwide. During World War II, domestic mining of celestite resources occurred in California and Texas. U.S. celestite mines had at that time been inactive since World War I, and all demand for strontium minerals was met from foreign sources.

Strontium carbonate, the most important strontium compound by far, was produced in 1990 by one company in the United States. CPC was the only company

that produced strontium chemicals from celestite. The majority of the celestite CPC used was imported from Mexico. CPC utilizes the black ash method of strontium carbonate production at its facility. The black ash method and the soda ash method are the two most common recovery techniques. The black ash method, known alternatively as the calcining method, produces chemical-grade strontium carbonate, which contains at least 98% strontium carbonate. The soda ash or direct conversion method produces technical-grade strontium carbonate, containing at least 97% strontium carbonate.

The black ash method received its name because the first step in the procedure involves mixing the crushed and screened celestite with powdered coal, making a black mixture. The mixture is then heated to about 1,100° C, expelling oxygen in the form of carbon dioxide from the insoluble strontium sulfate to form water-soluble strontium sulfide.

Strontium sulfide is dissolved in water, and the resulting solution filtered. Carbon dioxide then passes through the solution or soda ash is added. Either compound provides the necessary carbon and oxygen for strontium carbonate to form and precipitate from the solution. The precipitated strontium carbonate is then removed from the solution by filtering and is dried, ground, and packaged. The sulfur released in the process is either recovered as elemental sulfur or in other byproduct sulfur compounds.

In the soda ash method, ground celestite is washed and most of the water removed. The thickened mixture is then mixed with soda ash and treated with steam for 1 to 3 hours. During this time, celestite and soda ash react to form strontium carbonate and sodium sulfate. Sodium sulfate is water soluble, making it possible to separate the insoluble strontium carbonate by centrifuging. Although the soda ash method is a simpler process, the lower grade of the product causes it to be the less preferred method of recovery. The black ash method is the most common method of strontium carbonate production, and new production facilities usually use black ash technology.

CPC purchased the strontium nitrate production facilities from FMC Corp. in Modesto, CA, when that company discontinued production of carbonate and nitrate in 1984. The company moved the equipment to Cartersville and now is also the sole U.S. producer of strontium nitrate.

There are several U.S. companies that produced strontium compounds from strontium carbonate. Mallinkrodt Inc. of St. Louis, MO, produced strontium chloride, and Mineral Pigments Corp. of Beltsville, MD, produced strontium chromate. A few other companies produced downstream strontium compounds, but on a very small scale.

Domestic strontium deposits were operated in 1944 near Blanket, in Brown County, TX; in Nolan County, TX; in the Fish Mountains in Imperial County, CA; and near Ludlow, CA.[1] At that time, the major use for strontium chemicals was for pyrotechnic applications such as signal flares and tracer bullets required for military applications. Immediately following the World War II, this demand disappeared, causing domestic production of celestite to decrease quickly and eventually disappear.

Resources in the United States have been estimated at 3.2 million metric tons, with an identified reserve base of 1.4 million tons. The reserve figure includes material containing no more than 60% strontium sulfate, which is much too low grade to meet today's rigid specifications. In addition to deposits operated in the early 1940's, celestite has been discovered in Arizona, Arkansas, Kentucky, Michigan, Missouri, New York, Ohio, Pennsylvania, Tennessee, Utah, and Washington.[2]

Consumption and Uses

Approximately 80% of all strontium was consumed in ceramics and glass manufacture, primarily in television faceplate glass and ceramic ferrite magnets, and in smaller amounts in other ceramic and glass applications. In the past 20 years, color television production has become the major consumer of strontium. Because of unique properties that strontium compounds possess, technologies have developed that take advantage of those properties for specific applications. All color televisions and other devices containing color cathode-ray tubes sold in the United States were required by law to contain strontium in the faceplate glass of the picture tube. Strontium blocks X-rays better than barium, which was previously used, and although lead is a better X-ray barrier than strontium, it causes a browning of the glass, which makes its use undesirable. Major manufacturers of television picture tube glass incorporate about 8%, by weight, strontium oxide in their glass faceplate material. The strontium is added to the glass melt in the form of strontium carbonate, and during processing, it is converted to strontium oxide. In addition to blocking X-rays, the strontium improves the appearance of the glass, increasing the brilliance and improving the quality of the picture.

Trends in television production show a shift to larger, flatter tubes that require thicker glass, and therefore, more strontium. Although the television industry in the United States is considered mature, there is a continuing demand for replacement televisions as well as additional sets in large numbers of households. The trend to personal computers and sophisticated, computerized instrumentation increased the demand for strontium in color monitors for these devices.

Permanent ceramic magnets were another large end use for strontium compounds in the form of strontium ferrite. When these magnets were first developed, they were used primarily as magnetic closures for refrigerator doors. Applications have expanded to include extensive use in small direct current (dc) motors, especially for automotive applications such as windshield-wiper motors, as well as loudspeakers, other electronic equipment, toys, and magnetically attached decorative items.

Strontium ferrites are used in permanent ceramic magnets because they have high coercive force, high thermal and electrical resistivity, and are chemically inert. They retain their magnetism well, are not adversely affected by electrical currents or high temperatures, and do not react with most chemical solvents. Other properties that make the strontium magnets more attractive for specific applications are their resistance to demagnetization and lower density, making them more desirable in applications where weight is a factor.

Barium or lead can replace the strontium in ferrite magnets, but strontium ferrites have been found to possess the best combination of properties necessary for superior magnets.

One of the most consistent and continuing applications for strontium has been in pyrotechnic devices. Strontium burns with a brilliant red flame, and no other material has been found to be better in this application.

The strontium compound used most frequently in pyrotechnic devices was strontium nitrate. Some strontium compounds

are slightly hygroscopic, but strontium nitrate takes on very little water and imparts the desired brilliant red. Strontium carbonate, strontium oxalate, strontium sulfate, and strontium chlorate can be used in pyrotechnic applications, but strontium nitrate was used in significantly larger quantities than any of these.

Pyrotechnic devices were used in military and nonmilitary applications. Military pyrotechnic applications that contained strontium included tracer ammunition, military flares, and marine distress signals. Nonmilitary applications included warning devices and fireworks.

Strontium was used to remove lead impurities during the electrolytic production of zinc. Zinc used in diecasting alloys is required to contain less than 0.003% lead. Addition of strontium carbonate in sulfuric acid to the electrolyte reduced the lead content of the electrolyte and of the zinc that is deposited on the cathode.

The addition of strontium chromate to paint creates a coating that is resistant to corrosion. It is an effective coating for aluminum, most notably on aircraft fuselages and ships. These paints are used to some degree on aluminum packaging to prevent package corrosion. The nitrate and chloride contents of strontium chromate paint pigment are very strictly controlled to prevent corrosion.

Consumption of metallic strontium was still a very limited factor in total strontium consumption. Small amounts of strontium are added to molten aluminum to improve the castability of the metal, making it much more suitable for casting items that have been traditionally made from steel. The addition of strontium to the melt improves the machinability of the casting. The use of cast aluminum parts is currently gaining popularity in the automotive industry. Aluminum parts were impractical before modification techniques were developed. The reduction in the weight of the automobile by using cast aluminum parts instead of steel helps to improve energy efficiency of the cars incorporating these parts.

At the present time, other strontium end uses consume only small amounts of strontium and strontium compounds. As mentioned previously, the presence of strontium in glass applications improves the brilliance of the glass. It also improves the quality of certain ceramic glazes as well as eliminates the toxicity that may be present in glazes containing lead or barium. One high-tech strontium ceramic is strontium titanate, which is sometimes used as substrate material for semiconductors and also in some optical and piezoelectric applications.

Strontium chloride was used in toothpaste for sensitive teeth. For this application, impurities must be strictly controlled, with limits for some of them in the parts per million range.

Strontium phosphate was used in the manufacture of fluorescent lights, and the entire range of strontium chemicals was used in analytical chemistry laboratories.

Prices

The average customs value for celestite imported from Mexico was about $80 per ton ($73 per short ton). Mexico was the source of 89% of all celestite imports in 1990. Another 10%, valued at $190 per ton ($172 per short ton), was imported from Spain. Average value for total strontium imports was about $85 per ton ($77 per short ton). This value was slightly higher than the average customs value reported for 1989. Values of imported strontium compounds varied according to the type of compound and the country of origin.

Foreign Trade

According to the Port Import/Export Reporting Service of The Journal of Commerce, U.S. exports of strontium compounds were about 2,200 tons, a 58% decrease from the exports reported from the same source in 1989. Of these exports, 98% was strontium carbonate that went to Taiwan. Other reported strontium exports were chloride, chromate, ferrite, nitrate, and peroxide, all in relatively small quantities.

The Bureau of the Census began using the Harmonized Tariff Schedule in 1989 to identify material passing through U.S. customs. This system makes classification codes for imports and exports consistent internationally. With the adoption of the new codes, imports and export codes for strontium changed, and some formerly listed details are no longer available. Trade information for strontium metal was grouped with barium under a classification of other alkaline earth metals, making specific information concerning strontium unavailable. Strontium chromate data were eliminated. Other strontium compounds experienced changes in classification numbers, and the grouping of compounds differed.

According to reports from the Bureau of the Census, imports of celestite increased 90% from the levels reported in 1989. Nearly all of it was from Mexico and a small amount from Spain.

Mexico continued to grow in importance as a source for imported strontium compounds; the Federal Republic of Germany was second. Imports of strontium carbonate were virtually the same as in 1989; with imports from Mexico becoming a larger percentage of total imports. Strontium carbonate from the Republic of Germany continued to decrease as Mexico took over more of that market. Imports of strontium nitrate nearly tripled for the second consecutive year.

World Review

In almost all instances, celestite deposits occur in remote, undeveloped locations far from population centers in areas where inexpensive labor is available for mining. Huge deposits of high-grade celestite have been discovered throughout the world. Strontium commonly

TABLE 2

U.S. ESTIMATED DISTRIBUTION OF PRIMARY STRONTIUM COMPOUNDS, BY END USE

(Percent)

End use	1988	1989	1990
Electrolytic production of zinc	4	4	3
Ferrite ceramic magnets	11	10	9
Pigments and fillers	4	3	4
Pyrotechnics and signals	10	10	11
Television picture tubes	68	70	70
Other	3	3	3
Total	100	100	100

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM MINERALS,[1] BY COUNTRY

Country	1989		1990	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Mexico	25,640	1,956	46,484	3,727
Spain	—	—	2,234	425
Other	—	—	6	37
Total	25,640	1,956	48,724	4,189

[1]Celestite (strontium sulfate).
[2]Customs value.

Source: Bureau of the Census.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS AND METAL, BY COUNTRY

Country	1989		1990	
	Kilograms	Value[1]	Kilograms	Value[1]
Strontium carbonate:				
Canada	18,000	11,256	17,781	2,978
China	—	—	75,000	45,558
France	216,000	131,602	—	—
Germany, Federal Republic of	4,427,276	2,992,291	2,806,028	2,018,791
Italy	3,648	3,520	—	—
Japan	934,883	635,860	6,300	33,899
Netherlands	—	—	15,506,833	9,210,192
Mexico	12,872,502	6,669,611	36,000	24,760
United Kingdom	6,137	11,012	16	12,670
Total	18,478,446	10,455,152	18,447,958	11,348,848
Strontium nitrate:				
Germany, Federal Republic of	600	8,536	—	—
Italy	43,003	40,725	17,000	16,016
Mexico	571,849	546,291	1,661,385	1,586,517
Spain	18,000	17,100	36,000	30,618
Total	633,452	612,652	1,714,385	1,633,151

[1]Customs value.

Source: Bureau of the Census.

occurs with barium and calcium, two elements with properties very similar to strontium, thus making separation difficult. Because removing many impurities from celestite is difficult and energy intensive, current strontium chemical producers require material to contain at least 90% strontium sulfate. Most of the currently operating celestite facilities can produce sufficient supplies with only minimal processing necessary to achieve acceptable specifications. Hand sorting and some washing are all that are necessary at many strontium mines; only a few operations use froth flotation or gravity separation to beneficiate their ore.

Detailed information on most world resources is not readily available. Many of the large deposits are in remote, sparsely inhabited areas, and very little formal exploration has been done. Other deposits may be well identified but are in countries from which specific mineral information is not easily obtained.

Capacity.— The data in table 5 are annual rated capacity for chemical processing plants as of December 31, 1990. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Two types of strontium capacity exist, ore production capacity and compound production capacity. Strontium compound capacity was deemed the more important for several reasons. Essentially, all strontium is consumed in compound form, primarily as the carbonate and to a lesser extent as the nitrate. Strontium carbonate is also the intermediate product in production of downstream compounds. At least 12 countries mined celestite in 1989. Virtually all of the celestite mined annually is consumed in the production of strontium carbonate and other strontium compounds. Very little strontium was consumed directly in the mineral form.

Listing both ore and compound production capacity could be misleading, possibly resulting in double-counting of strontium capacity. Because most ore is produced for market by means of very simple sorting and beneficiation techniques, capacity can easily be raised to meet increased demand. Strontium carbonate production capacity is the limiting factor in strontium production, requiring complicated and sophisticated processing facilities. Therefore, strontium carbonate production capacity, reported in terms of contained strontium, was selected for tabulation. Construction to expand strontium carbonate capacity has increased because of the continued growth in international sales of color television sets. Capacity information was compiled from published reports.

Algeria.—Celestite was mined in Algeria from a surface deposit near Beni Mansour. Estimated reserves were more

TABLE 5

WORLD STRONTIUM CARBONATE ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1990

(Metric tons)

Country	Rated capacity[1]
North America:	
Mexico	65,000
United States[2 3]	22,000
Total	87,000
Europe:	
Germany, Federal Republic of[2]	15,000
Spain	8,000
U.S.S.R	(4)
United Kingdom	(4)
Total	23,000
Asia:	
China	1,800
Japan[2]	31,000
Korea, Republic of	40,000
Total	72,800
World total	182,800

[1]Includes capacity at operating plants as well as plants on a stand-by basis.
[2]Production was entirely from imported celestite.
[3]Includes strontium nitrate production capacity.
[4]Strontium carbonate production capacity existed in these countries, but specific data were not available.

than 1 million short tons. The deposit was mined by Enterprise des Produits Non-ferreux et des Substances Utiles (ENOF) and was controlled by L'Enterprise Nationale de Developpement Minière (Edemines), a division of Société Nationale de Recherches et d'Exploitations Minières (SONAREM). No strontium has been exported in recent years, but in the past, up to 3,600 tons per year has been exported to nations in Eastern Europe and the Federal Republic of Germany. Although the celestite was relatively low grade, only about 70% strontium sulfate, it contained low concentrations of barite, silicate, gypsum, and iron, making it possible to concentrate the ore to acceptable levels using only gravity separation. The deposit has not been fully exploited, but there is interest in further development.[3]

Argentina.—Celestite mining was controlled by the Argentine Mining Union at the San Juan Mine in the Province of Mendoza. Celestite has been identified at several other small mines, the Maria Del Carmen and Don Luis Mines also in Mendoza Province and the Rayoso, Julio, Cerro Partido, and Llao Llao Mines in the Province of Neuquen. It is unlikely that any production was carried out on a regular basis at these mines. Most Argentine production was exported to Brazil.[4]

Canada.—Canada has produced celestite ore in the past from the McRae deposit, also known as the old Kaiser Celestite Mining Ltd. mine. It is at Enon, Cape Breton County, Nova Scotia. Mineral rights were acquired by Timminco Metals, a division of Timminco Ltd. of Toronto. Exploration identified reserves of more than 1 million tons of celestite, with grades ranging from 60% to 65% strontium sulfate. Reopening the mine has been considered, but the low grade of the ore makes economic feasibility questionable. Other strontium deposits have been identified in British Columbia, Newfoundland, and Ontario,[5] but none as significant as the deposit in Nova Scotia. Timminco Metals was the largest producer of strontium metal in the world and the only producer of strontium metal in North America. The company operated a processing facility in Westmeath, Ontario. The strontium production facilities in Westmeath and facilities in Haley, Ontario, produce strontium metal by the aluminothermic reduction of strontium oxide.

China.—Celestite was mined in China almost exclusively for domestic consumption. An ore-dressing facility at the Nanjing Mine in Jiang Su Province has a capacity of 10,000 tons per year. The Nanjing deposit is reported to be high grade and close enough to the surface for open pit mining.[6] Past import data indicated that strontium chemical plants must exist, but no specific details were available. Reports indicated that Japan imports strontium carbonate from China and that strontium carbonate from China has also been reported in the United States.

Cyprus.—Celestite mining began in Cyprus in 1985 at Vassliko, near Limassol, in southern Cyprus. The mine was operated by Hellenic Mining Co. Ltd. The ore averaged about 54% strontium sulfate and, therefore, required concentration to make it marketable. The ore was beneficiated through a flotation process to reach 94% strontium sulfate. The reserves have been determined to be 200,000 tons of celestite.[7] No mining has occurred for the past 3 years.

Germany, Federal Republic of.—Kali-Chemie AG of Hannover produced strontium carbonate from imported celestite at its plant at Bad Hoenningen. The major western European producer used the black ash method in the production facilities. Plant capacity is estimated to be 15,000 tons per year. Kali-Chemie imported most of its celestite from Spain and Turkey; it exported 80% to 90% of the production, most of which goes to the United States and the Republic of Korea. Kali-Chemie also produced strontium hydroxide and strontium nitrate. The nitrate was produced by its Italian subsidiary, Societa Bario e Derivati SpA, in Massa.[8]

Iran.—One of the world's largest celestite deposits is in the northwestern part of the Dasht-e-Kavir salt desert. The deposit was mined by Iran Strontium Co., a subsidiary of Cherkate Sahami Sanati Va Maadani Irani (Simiran). Average strontium sulfate values for the deposit were reported at more than 91%, but there were unfavorably high levels of barium sulfate and calcium sulfate. Proven reserves total 1.8 million tons of celestite, 430,000 tons of which has no overburden.[9] Most of the celestite produced from this deposit is believed to go to the U.S.S.R.

Italy.—Mining has been done by Minera Chimica Farnesiana SpA in Tarquinia, near Rome. Most production of this 75% strontium sulfate and 5% barium sulfate product was sold domestically. Annual production capacity at the mine was 7,300 tons per year, but production ceased in 1988. Some of the processed ore has been exported to the U.S.S.R. in the past. Other deposits are known to exist in the interior of Sicily, although none are presently being mined. Societa Bario e Derivati, a subsidiary of Kali-Chemie AG of the Federal Republic of Germany, produced strontium nitrate at Massa. Production and capacity figures were not available, but it was known that most of the production is exported to the United States.[10]

Japan.—No celestite was mined in Japan, but that country was the largest consumer of strontium carbonate in the

TABLE 6

STRONTIUM MINERALS: WORLD PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country[2]	1986	1987	1988	1989	1990[e]
Algeria[e]	5,400	5,400	5,400	5,400	5,400
Argentina	1,133	1,349	r2,241	r1,193	1,200
Cyprus (celestite)	7,365	6,300	—	—	—
Iran (celestite)[3]	r20,066	r39,194	r56,849	r,e55,000	55,000
Italy	4,667	177	—	—	—
Mexico (celestite)	24,042	47,739	r51,626	r51,755	52,000
Pakistan	997	r1,114	488	r956	1,000
Spain	34,500	r28,867	e40,000	e40,000	40,000
Turkey	r40,000	r49,000	54,000	e59,000	60,000
United Kingdom	14,739	22,655	25,553	r20,885	20,000
Total	r152,909	r201,795	r236,157	r234,189	234,600

[e]Estimated. [r]Revised.

[1]Table includes data available through May 24, 1991.

[2]In addition to the countries listed, China, Poland, and the U.S.S.R. produce strontium minerals, but output is not reported quantitatively, and available information is inadequate to make reliable estimates of output levels.

[3]Data are for year beginning Mar. 21 of that stated.

world, mostly due to its large television and electronics industry. Four companies produce strontium carbonate from imported celestite. Honjo Chemical Corp. operated a production facility for 18,000 tons per year of carbonate at Neyagawa in Osaka using celestite from Spain and China. Sakai Chemical Industries Co. also produced strontium carbonate, by the black ash method, in Osaka at a 12,000-ton-per-year plant using Chinese, Mexican, and Spanish celestite. Japan Special Chemicals (Nihon Tokushu Kasei) and Dowa Chemicals also produced strontium carbonate, but on a much smaller scale. The total capacity for both companies was only about 1,100 tons per year. These two companies used celestite from Spain.[11]

Korea, Republic of.—Although celestite deposits have not been identified in Korea, its growing electronics and television industry prompted a European company to form a joint venture with a Korean firm. Kali-Chemie and Samsung Corning Ltd., Korea, formed Daehan Specialty Chemicals Co. Ltd. to build a strontium carbonate and barium carbonate plant. The plant began operation in 1990 with a production capacity of 40,000 tons per year of strontium carbonate and barium carbonate, combined. The production will be targeted to the growing television industry in that country. The black ash method will be used.[12]

Mexico.—Two companies announced plans to build production facilities in the North. CPC planned to build a strontium carbonate plant in Reinosa, Tamaulipas, close to the U.S. border. Capacity should be about 22,000 tons per year.[13] Quimica Dinámica SA de CV, a Monterrey company that currently produces 8,000 tons of strontium carbonate, formed a joint venture with an unnamed Japanese company to create Cistron Mexicana SA de CV. The new company is expected to build a strontium carbonate plant initially designed to produce 30,000 tons per year, with a possible doubling of capacity in a second phase of construction.[14]

Strontium carbonate production has been a recent development in Mexico. This is a very attractive location for additional production facilities because of the huge celestite resources in the country. After a major U.S. strontium carbonate and strontium nitrate producer (FMC Corp.) closed its plant in 1984, Cia. Minera La Valenciana SA (CMV) bought the strontium carbonate processing equipment from the FMC plant in California. The plant, which utilized the soda ash method of carbonate production and was converted to the black ash method, was relocated to Torreón in Coahuila State, near a company-operated mine. The plant capacity is 50,000 tons per year. Shipments from the plant, targeted for the television and electronics industry in the Far East, commenced in May 1987. Sales y Oxidos (SYOSA), 49% owned by Kali-Chemie, built a new strontium carbonate plant near Monterrey with the capacity of 15,000 tons per year. The company's old strontium carbonate operation will be converted to produce barium carbonate. SYOSA, which produced carbonate by the black ash method from celestite it mines nearby, marketed its production in the United States.[15]

Mexico was one of the world's largest producers of celestite in 1990. The most recent Directory of Mexican Non-Metallic Minerals Trust lists 11 companies currently mining celestite. CMV mined celestite from the San Agustin deposit near Torreón, and Compañía Minera Ocampo SA mined a deposit near Saltillo in Nuevo Leon State, as well as some small production in Hidalgo, Aguascalientes, and Chihuahua States. Reserves of the San Augustin Mine alone have been estimated at more than 725,000 tons. SYOSA mines west of Monterrey. Other small operations occur in Coahuila, Aguascalientes, Chihuahua, and Nuevo Leon. Mexican celestite is primarily high grade, and only hand sorting is required to achieve at least 92% strontium sulfate with low barium content. Abandoned mines and easily identified deposits that have not yet been developed are common throughout a large area in northern Mexico. Reserves are believed to be vast, but these deposits have not been extensively explored.[16]

Pakistan.—All mines in Pakistan are the property of Provincial governments and are operated by private companies for the governments. Recent celestite production figures have been reported for two active mines, one near Dawood Khail and one near Karachi.[17] Tawakkal Mineral Exports Corp. recovered celestite from these mines in the Dadu District of Sind Province. No beneficiation was necessary to produce 94% strontium sulfate. Reserves of celestite have not been quantified at this location.[18] Other deposits, with 500,000 tons of reported reserves, have been identified in the Punjab Province.[19]

Spain.—Spain was another of the largest celestite producers worldwide. Celestite was produced from the Montevive deposit, which was operated by Herederos

de Aurelio Farjardo Vilches, with sales and marketing handled by Bruno SA. Selective mining and hand sorting was all that was necessary to produce ore grades of more than 92% strontium sulfate, although a concentration plant has been constructed. Reserves are believed to be at least 2 million tons. Most Spanish production is exported to Japan, some remains in Spain, and the rest is exported to the Federal Republic of Germany.[20] Promotora de Industria del Sur (Proinsur SA) produced strontium carbonate and strontium nitrate at a combined facility near Granada. The plant has a theoretical design capacity of 8,000 tons per year of carbonate, but has never reached this capacity. Strontium carbonate was produced by the soda ash method. The plant also has a production capacity of about 3,000 tons per year of nitrate, which has not yet been fully utilized.[21]

Turkey.—Turkey competes with Mexico, Spain, and Iran in claiming the world's largest strontium reserves. Barit Maden Turk AS produced celestite from a mine near Sivas. Run-of-mine ore was gravity separated to produce a concentrate with a minimum of 95% strontium sulfate. Because of the harsh climate in the region, the mine can only be operated on a seasonal basis, from May to October. Another mine near Sivas was formerly operated by Bilfer Madencilik AS, which reestablished concessions for future celestite mining. Identified reserves have been placed at 550,000 tons, and further reserve potential is estimated to be greater than 2 million tons. Turkish celestite was primarily exported to the Federal Republic of Germany.[22]

U.S.S.R.—Very little is known about Soviet production of strontium minerals. Deposits are known in the Karakum Desert, Zaunguz Plateau; Permian deposits near Bashkir; caprocks of the Romy and Isachkov salt domes; Pinega area, Archangel Province; Yakutsk, eastern Siberia; and in Turkestan from eastern Fergana to the shores of the Caspian Sea, and from southeastern Bucharia to the shores of the Sea of Aral. Reserves are believed to be very large, but the ore grade is probably not high.[23] No details are available concerning the production of strontium carbonate in the U.S.S.R. except that there is production, probably from domestic celestite as well as from imports from Iran and Turkey.

United Kingdom.—Celestite deposits, which occur in the Bristol area, were mined by Bristol Minerals Co. Ltd. The ore is crushed, washed, and graded to achieve a product with 95% strontium sulfate. Reserve estimates vary from 100,000 to 500,000 tons. The British deposits continue to be encroached upon by large-scale housing developments, limiting possible exploitation of the minerals to the near future. This was one of the few sites where celestite deposits are not in remote locations.[24]

Current Research

Strontium-90, a radioactive isotope of strontium, is a component of nuclear waste from reactors and nuclear fallout. It presents special problems for waste disposal and storage because it generates a significant amount of heat as it decays. When released into the atmosphere through nuclear testing or accidents, it easily enters the food supply in milk and vegetables because it is so similar chemically to calcium. Scientists at Argonne National Laboratory have developed a process for removing strontium-90 from liquid nuclear waste.

The method known as SREX dissolves more than 99.999% of the strontium-90 from the waste stream in a special solvent. Pure strontium-90 is then removed from the solvent with water or dilute acid. The recovered strontium-90 could be used in radio-isotopic thermal generators that are used in devices such as harbor markers, which require long-lasting, unattended power supplies.[25]

OUTLOOK

The future continues to look bright for the strontium industry for the near term, although if both planned operations in Mexico are actually accomplished, a serious oversupply situation could occur. Continued growth is expected in the color television industry, and larger screens are expected to increase in popularity. Demand for strontium carbonate for television application should expand likewise. Other markets will probably continue at their current, slower rate. Development of a technology to produce an affordable flat television display could severely reduce the demand for strontium carbonate. Although a high-quality, large, flat screen is not yet available, small models are, and research continues to perfect the technology. The question remains whether a new display system can be developed that will be economically attractive to the general public. Initial devices are expected to find application in military hardware and other sophisticated medical and scientific instrumentation. Flat screen display systems may eventually replace cathode-ray tubes, and, at that point, strontium producers may experience a serious setback.

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